

A Bit About Forth

Dave Eckhardt
de0u@andrew.cmu.edu

Disclaimer

- I don't know Forth
- Forth tutorials abound on the Web
 - Intro: stack, postfix stack operators
 - Writing a simple Forth word
 - Loops
 - Stack manipulation, simple built-ins
 - Gee, tutorials take forever to write, so close with:
 - 100%-inscrutable example using Forth's full power
- I am ~40% through the inscrutable stage

Outline

- Forth is a language with
 - No syntax¹
 - No operator precedence
 - No operators
 - No functions
 - No variables
 - No constants
 - No loops²

No Syntax

- Well, hardly any
 - “Whitespace-delimited sequence of digits” (in the current input radix) is recognized as a number.
 - In many dialects, a dot in a number is allowed for readability or to signal double precision
 - “Whitespace-delimited sequence of characters” is a “word”.

Syntax Examples

- 123
- FFEB.09CA
- >entry
- 2dup
- \$entry
- *, +, -, /, etc.

No Operator Precedence

- Easy: no operators!
- In C, + and && and || are part of the language
 - So the language arranges for them to be evaluated according to “natural” precedence (more or less)
- In Forth, all executable things are of the same class (“word”)
- Precedence is manual (postfix stack ops)

Stack Operations

3 4 +

- Push 3 (a number) onto the stack.
- Then push 4 (a number) onto the stack.
- Run +

- Which traditionally pops two integers from the stack, adds them, and pushes the result on the stack. But it could be redefined to do anything else instead.

- “3 + 4 * 2” - meaning is up to you, not to Forth

3 4 2 * +

3 4 + 2 *

No Functions

- Words aren't functions
 - They have no types
 - No parameter types
 - Words pull whatever they want off the stack
 - First parameter may determine how many parameters
 - Or the second, if you want
 - No return types
 - Words push whatever they want onto the stack
 - Common idiom:
 - success $\Rightarrow$ push answers, then push “true” (-1)
 - failure $\Rightarrow$ push “false” (0)
 - Actually, nothing has any types

No Types

- What is the type of items on the stack?
 - “Cell” - approximately “machine word”
 - Same type as BLISS (great-grandfather of C, used to write DEC's VMS, CMU's Hydra)
- Some words operate on multiple cells (“extended precision”)

No Variables

- Most code operates on stack values
- Once you have “too many” values on your stack your code gets confusing
- There is a word called **VARIABLE**
 - It doesn't “declare” a “variable”, though.
 - It allocates a cell and compiles a word that pushes the address of that cell on the stack.

VARIABLE F00

F00 @ 3 + \ Get contents of F00, add 3

VALUE

- If a “variable” will be read more than written, you can use **VALUE** instead.
 - It places a value into a freshly-allocated cell and compiles a word that fetches the contents of the cell and pushes it on the stack

0 value BAR

BAR 3 + \ Get BAR contents, add 3

4 TO BAR \ sets BAR to 4 - advanced

No Constants

- There is a word called **CONSTANT**, though.
 - Can you guess what it does?

No Loops

- The language *does* ship with words that implement loops

10 1 DO I . CR LOOP

- But these words aren't privileged – you can write your own which work just as well.
 - **UNLESS, UNTIL, WHEREAS...** - go wild!

Is There Anything There?

- No...
 - No syntax¹
 - No operator precedence
 - No operators
 - No functions (no types)
 - No variables
 - No constants
 - No loops²
- So what *is* there?

Parts of Forth

- “The Stack”
 - Really: the operand stack
 - Versus the *other* stacks
 - Call/return stack – (ab)used by loop words
 - Exception stack – if exceptions are available
- The Dictionary
 - Maps word names to execution tokens
- The “Compiler”
- The “Interpreter” (read loop)

“Compiler”

- “Compiler” stitches together code bodies of existing words

: addone 1 + ;

- Looks like a “function definition”, beginning with the “:” token and ending with the “;” token
 - Nope!
- : (a word like any other word) grabs a word from the input stream, saves it “somewhere”, and turns on “the compiler”
- “The compiler” creates code sequences for pushing numbers and pushing calls to words

“Compiler”

- When “the compiler” sees `;` it adds a dictionary entry mapping the saved name-token to the execution-token sequence
- Where's the code?
 - Here comes a vague analogy...
 - ...C code which when compiled would have similar effect to Forth...

The Code

```
/* “threaded code” style */  
  
typedef void (*notfun)(void);  
notfun push1, plus;  
notfun addone[] = { push1, plus, 0 };  
  
void execute(notfun a[])  
{  
    while (a[0])  
        (*(a++))();  
}
```

Threaded Code

- Easy to generate machine code which just calls other machine code
- Also easy to generate machine code for “push integer onto stack”
- Handful of built-in words must be written in assembly language
 - Peek, poke (@, !)
 - +, -, *, /
 - Compiler itself

Isn't Threaded Code Slow?

- Other organizations are possible
 - Can peephole-optimize threaded code pretty well
 - Can “cache” top N words of stack in registers
 - Can do a real optimizing compiler if you want

Are We Having Fun Yet?

- Why would people do this?
 - Great for memory-constrained environments
 - Forth runtime, including compiler, editor, “file system”, “virtual memory” can be implemented in a few *kilobytes* of memory
 - Stacks are very small for real applications (small number of kilobytes)
 - *Very* extensible
 - Want software VM? Just redefine @, !
 - “Hard” things may be trivial
 - De-compiling Forth is often very easy...

Are We Having Fun Yet?

- Why would people do this?
 - A trained person can bring up a Forth runtime on just about any system in around a week given assembly-language drivers for keyboard and screen
 - GCC+glibc ports to new processors typically take a *little* longer than that...

Is Forth Usable?

- It's missing:
 - types, type-checking, pointer-checking
- How can code written this way work?

Is Forth Usable?

- It's missing:
 - types, type-checking, pointer-checking
- How can code written this way work?
 - Oddly enough, very well.
 - Forth advocates claim it promotes careful thought. Also, most words are short enough to be solidly tested.
 - Another slant: No way to avoid paying attention.
 - Another slant: anybody who can wrap their mind around it is a **very** good programmer...

Curiosity or Language?

- Who uses this?
 - OpenFirmware (every Macintosh ~1996-2006)
 - PostScript allegedly was inspired by Forth
 - Embedded firmware
 - Astronomers...since the 1960's
 - **Lots** of things in space run/ran Forth
 - <http://web.archive.org/web/20101024223709/http://forth.gsfc.nasa.gov/>

Who Should Learn Forth?

- Long-hair hacker types might find it fun
- Embedded-systems programmers might find it useful
- CS majors might find it challenging
- Its era might be over...
- Don't tell your ML instructor I told you about it

Further Reading

- Forth - The Early Years
 - <https://web.archive.org/web/20160304065437/http://www.colorforth.com/HOPL.html>
- The Evolution of Forth
 - <http://www.forth.com/resources/evolution/>
- Forth OS
 - <https://web.archive.org/web/20180309111340/http://www.forthos.org/>